Analysis of Sea Bird Distribution in the Northwest Pacific Ocean

NAGAHISA KURODA[1]

THIS PAPER is based on data obtained by the author on board the fur seal research ship, "Geizan Maru," No. 8 (capacity, 78 tons), of the Japanese Fisheries Bureau, between June 4 and July 14, 1954, on a trip from Japan to the west Bering Sea. This paper presents the relative abundance of sea birds by divisions of sea zones, and discusses their correlation with air and water temperatures. Specific records on birds and sea mammals have been reported in other places (Kuroda, 1955, 1956) and a diary of the cruise has been prepared (in MS).

METHOD

All of the sea birds observed were recorded, together with pertinent data upon the time, air and water temperatures (these were regularly measured every hour by the crew), and the location in longitude and latitude. When flocks of birds were seen, their number was estimated. The author was the observer for an average of seven hours a day, with two or three rest periods. The records were arranged in a table under each observation time. The numbers of individuals observed per day and per hour were calculated (Table 1). Specimens of almost all of the species recorded were obtained (Kuroda, 1955).

GENERAL REMARKS

Although it was the breeding season, observations were concerned chiefly with nonbreeding populations of sea birds, since the ship took a pelagic course.

The density of sea birds can be given by linear and dimensional estimates. The linear estimate may be either per unit of time or per unit distance of travel. In this paper, the number of birds observed per hour, at a ship's speed of seven miles per hour, was used for various analyses. For the absolute population density of sea birds, the following formula, which was developed in research upon the fur seal (Austin & Wilke, 1950: 35; also in 1954) might be applied:

$$\text{Number of birds per square mile} = \frac{\text{Total number of birds observed}}{\text{Distance passed during observation (in miles)} \times 0.114}$$

The fur seal frequently rests on the water, exposing only small parts of its head and flippers. The figure 0.114 mile is the distance to each side of the ship at which the seal can be visually detected when in this position. To collect adequate data for a certain sea area, several ships should work, as in the fur seal census, or a single ship should take a zigzag or irregular course to cover a greater part of the sea area by that "sight range belt." In our research, the latter type of course was taken in the northern sea and dimensional bird density was calculated tentatively, applying the above formula for subdivisions of this sea zone (Table 2). But the significance of the sight range of 0.114 mile in the study of birds needs future study, and, in actuality, all of the identifiable species of birds were recorded, irrespective of distance. It has been our experience, however, in many cruises off Japan, that floating sea birds were often identified at about the same range as the fur seals were detected, although a closer range was necessary to identify such similar species as *Synthliboramphus antiquus* and *S. wumizusume,* because binoculars are not usable, owing to vibration on a small research ship. On the other hand, flying birds, especially when in flocks, can be seen and identified at much greater distances, but some closely similar species, such as *Puffinus tenuirostris* and *P. griseus,* must often be identified at a closer range. Moreover, weather, direction of sunlight, and wave conditions influence very much the visibility and the success of the observer's identifications.

[1] Yamashina Museum of Birds, 49 Nanpeidai-machi, Shibuya, Tokyo, Japan. Manuscript received March 5, 1958.

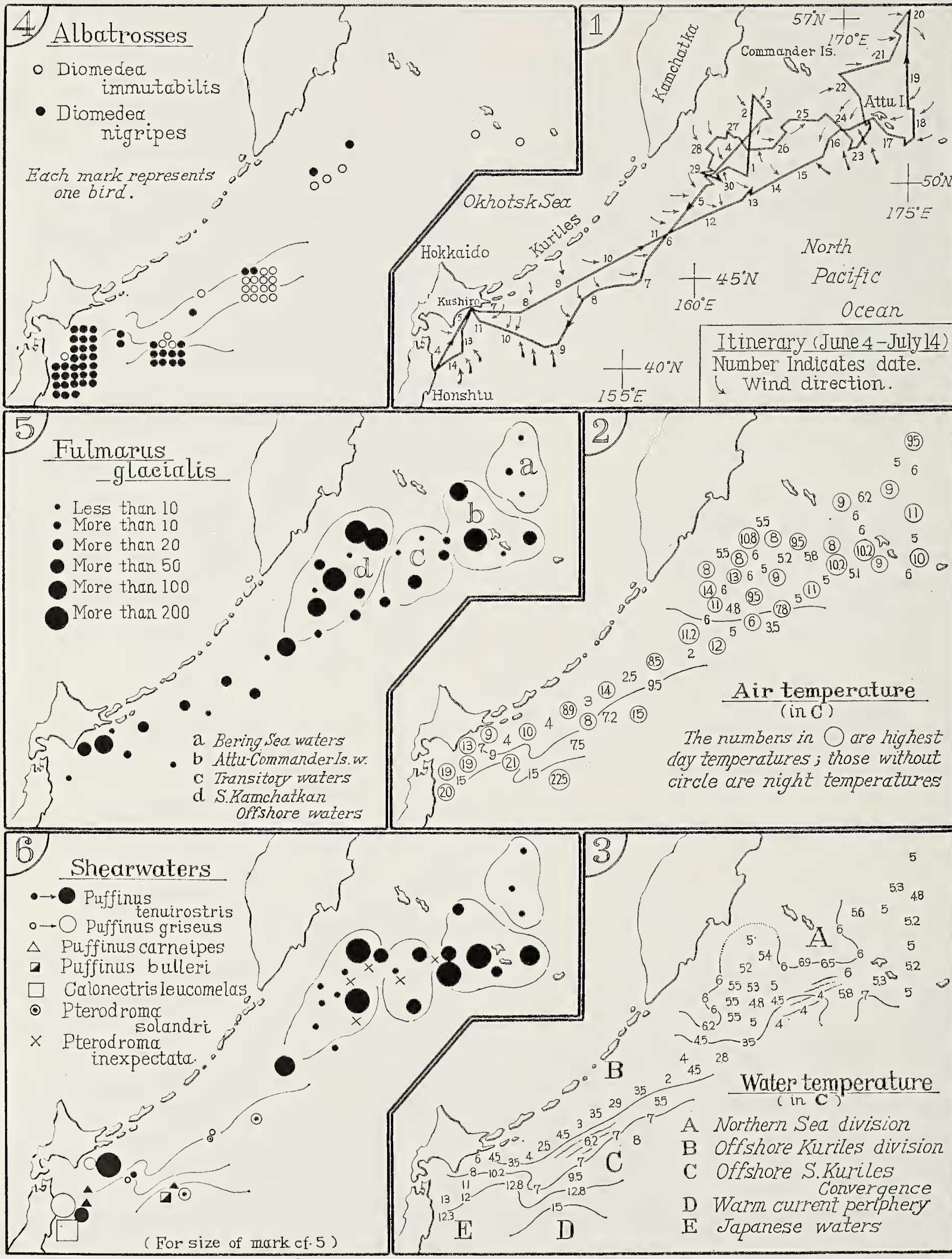


FIG. 1*a*. Maps showing the oceanographic conditions, sea divisions, and distribution of the birds observed and collected. Bird abundance is based on daily counts of individuals.

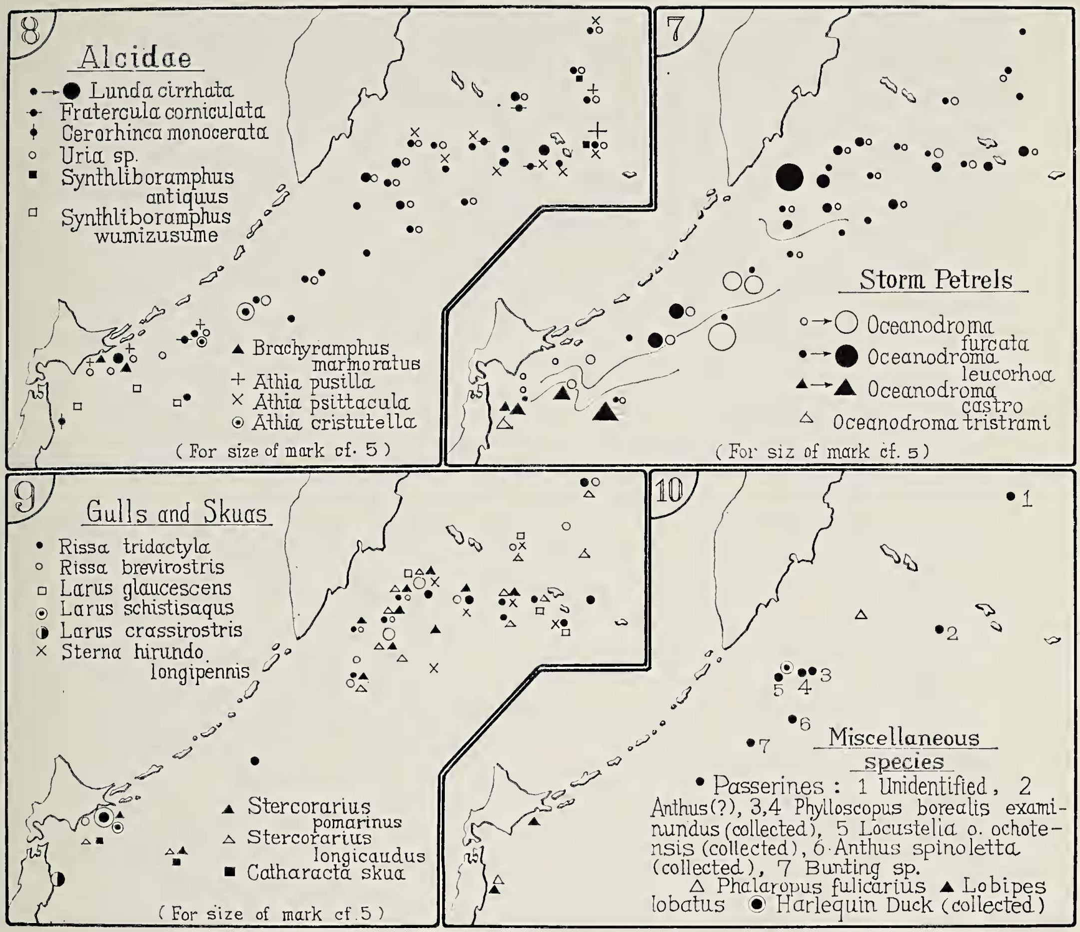


FIG. 1*b*. Maps showing the distribution of the birds observed and collected.

For comparative study of sea bird distribution, specific relative abundance within a sea zone and zonal relative abundance inclusive of all species occurring in the zone, will be considered. The distribution of sea birds is subject to three general sources of variation: zoogeographic (endemism), ecological (food and temperature dependent), and seasonal (physiological cycle and migration). These factors influence the occurrence of various species and the relative abundance of birds in different sea zones.

Each species has its range of physiological tolerance to temperature, both in air and in water, although this is less strict in some species and varies seasonally to some extent. Furthermore, a few individuals may stray out of this range, and long-distance migrants of cold currents cross the tropical seas. Within a preferred temperature sea zone, the food supply and interspecific relation in some cases determine the local relative abundance of sea birds and form a basis for subdividing the sea zone.

The *specific relative abundance* of sea birds within a sea zone was estimated by the "specific lowest density" per hour (of Elton, 1953: 51), which is:

$$\frac{\Sigma \text{ Number of birds observed per hour}}{\text{Total number of observation days}}$$

In this calculation of lowest density are included the days on which the species has not been recorded. Therefore, it is lower than the

TABLE 1

AN EXAMPLE OF THE DAILY RECORDS AND NOTES FROM THE AUTHOR'S OBSERVATION DIARY

OBSERVATION TIME	6:00–7:30 a.m.	11:00–15:00	16:00–18:00	Total time: 7:30 hours	Number observed per hour (7 miles)
AIR TEMPERATURE (°C.)	7–9	9–11	7.5–6	Distance: 52 miles	
WATER TEMPERATURE (°C.)	4.2–4.3	4	4		
				TOTAL	
Fulmarus glacialis	3	51	10 (white 1)	64 (white 1)	8.76
Oceanodroma furcata	3	3	7	13	1.78
O. leucorhoa	—	—	1	1	0.13
Puffinus tenuirostris	—	40	11	51	6.98
Lunda cirrhata	3	1	—	4	0.54
Total	9	95	29	133	18.19
Fur Seal	1	—	—	1	—
Phocaenoides dallii	—	about 5	—	5	—

Date: June 15. Cloudy, occasional fine rain. Air pressure: 1008 mb.

Wind: E–ESE (1–0), dead calm. 270–200 miles WSW of Attu Is.

Note: Passed 50° N. latitude, heading toward Attu. Fulmar increased (white one seen at 167° 28′ E., 50° 52′ N.) and a flock of *P. tenuirostris* occurred, flying to E–NE, obliquely against winds. Water temperature changed from previous 3° C. to 4° C., with demarcating line NE–SW.

"economic density" of Elton, which is the density of a species when it occurs, calculated by this formula:

$$\frac{\Sigma \text{ Number of birds observed per hour}}{\text{Number of days the species was observed}}$$

Then, the species' abundance (general or localized distribution) is suggested by the "occurrence rate," which is:

$$\frac{\text{Number of days the species was observed}}{\text{Total number of observation days}}$$

Therefore, from these formulae, the following relation exists between the lowest and economic densities:

$$\text{lowest density} = \text{economic density} \times \text{occurrence rate}$$

The *areal relative abundance* of sea birds was compared by the areal "lowest density" per hour, which is:

$$\frac{\Sigma \text{ Number of birds of all the species observed per hour}}{\text{Number of observation days}}$$

and the "abundance rate of species" was calculated by:

$$\frac{\text{Mean number of species which was observed per day}}{\text{Total number of species observed}}$$

The *distributional pattern* of species depends upon their habits. If systematic areal census of the sea birds could be made, they would show interesting distributional patterns (Odum, 1954: 154; Torii, 1952) by species and by sea zones. Flocking species, such as shearwaters, concentrate in a clustered pattern where food is abundant; the phalaropes, which feed on plankton, show a patchy pattern of small groups; while the tufted puffins usually occur at random singly or in pairs. Possibly in the case of the puffins, a sparse food supply is enough to sustain their solitary life on the ocean.

TABLE 2

POPULATION DENSITIES OF SEA BIRDS IN THE SUBDIVISIONS OF THE "NORTHERN SEA DIVISIONS"

SEA AREAS	NUMBER OF BIRDS OBSERVED PER DAY	NUMBER OF SPECIES OBSERVED	NUMBER OF BIRDS PER HOUR (AT 7 MILES)	NUMBER OF BIRDS PER SQUARE MILE
W. Bering Sea	38	8	7	7.42
Attu–Commander Is.	307	10	40	49.11
In Transit	112	8	17	21.19
Offshore S. Kamchatka	280	9	50	59.81

Data on 10 chief species of birds recorded in the Northern Sea Division are analyzed in Table 3 and Figure 2. The mean economic density roughly represents the general specific density, but by inclusion of some concentrated and irregular densities, the species' most frequent density, the mode, is obscured (Table 3). In the Tubinares (*Fulmarus glacialis, Puffinus tenuirostris,* and *Oceanodroma furcata*) the range of observed densities is very wide, because they usually occurred sparsely during the day and often formed a large feeding flock, especially in the early morning. (*O. leucorhoa* was an exception, but its chief concentration was outside of this sea division.) These two patterns of distribution were well marked, as shown in Figure 2A; the most frequent densities of usual sparse distribution (the mode) were 1–3 birds per hour, while the concentrated densities (the "highest density" of Elton) were as high as 30–70 birds per hour. In other sea birds, such as alcids and gulls, such a "highest density" concentration was not found. But their numbers increased (Fig. 2B; June 23, July 2–5, etc.) when they were found among a mixed community, with porpoises and perhaps some fishes under the water feeding upon euphausids. The dominant birds were *Fulmarus glacialis* and/or *P. tenuirostris.* One such fulmar-dominated concentration was found close to a mother ship (6,000 tons) of the Japanese salmon fishery, on July 4–5.

Puffinus tenuirostris birds are migrants from the southern hemisphere and *Fulmarus* was represented perhaps chiefly by a nonbreeding population. Some breeding adults (a bird with large ova was collected), as well as some molting young of *Lunda cirrhata,* were found as far as 200 miles offshore, and they were distributed rather uniformly, with a density of 1–3 birds per hour. But a species of *Uria* seemed to be less pelagic in distribution and only a sparse peripheral population was encountered, since the usual densities were 0.1–0.2 birds per hour. *Rissa* spp. are gregarious pelagic gulls, but apparently only some nonbreeding birds were found, inasmuch as their distributional pattern was sparse and irregular.

DIVISIONS OF SEA ZONES

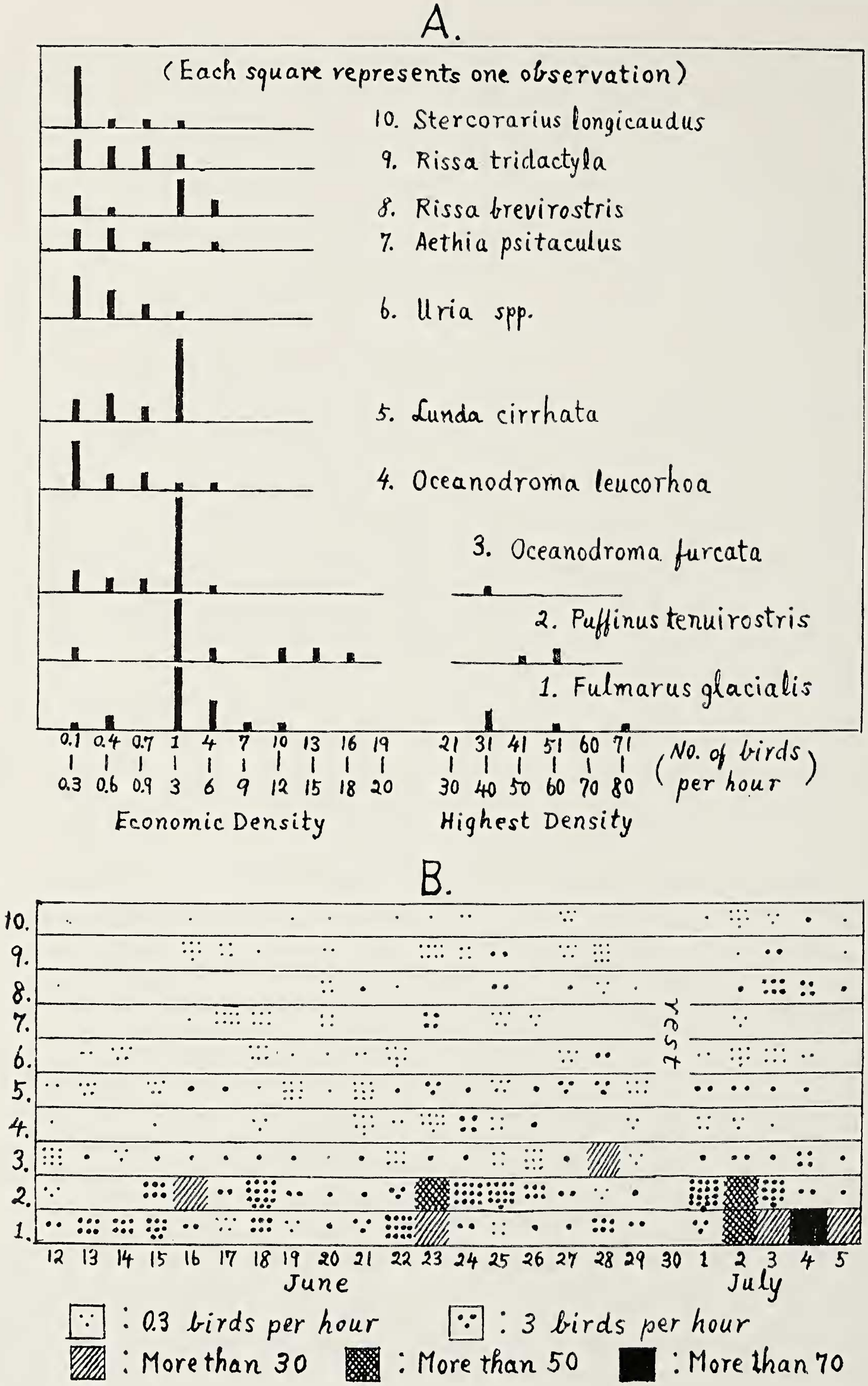
The cruise track of the "Geizan," No. 8, and the sea divisions traversed, are shown in Figure 1. Oceanographic conditions (Kuroda, 1955) and sea bird distribution in each division and subdivision are briefly given below (see also Figs. 1, 3, and Table 4).

A. *Cold Current Sea Surface*

From the northern seas the cold current stretches along the Kuriles (at least to 100 miles offshore) south to Hokkaido. The dominant species of sea bird was *Fulmarus glacialis.* Other generally distributed species were: *Puffinus tenuirostris* (rare along the Kuriles), *Lunda cirrhata, Oceanodroma furcata* (rare off the central Kuriles and southward), and *O. leucorhoa* (rare in the northern seas).

1. Northern sea division

North of about 50° N. latitude. The air and water temperatures were most often 5°–6° C. and 8°–10° C. respectively. At night water temperatures often fell to 5° C. Zoogeographic species characteristically not found southward were: *Rissa brevirostris* (see its


A.
(Each square represents one observation)
10. Stercorarius longicaudus
9. Rissa tridactyla
8. Rissa brevirostris
7. Aethia psitaculus
6. Uria spp.
5. Lunda cirrhata
4. Oceanodroma leucorhoa
3. Oceanodroma furcata
2. Puffinus tenuirostris
1. Fulmarus glacialis
0.1–0.3 0.4–0.6 0.7–0.9 1–3 4–6 7–9 10–12 13–15 16–18 19–20
21–30 31–40 41–50 51–60 60–70 71–80
(No. of birds per hour)
Economic Density
Highest Density
B.
10. 9. 8. 7. 6. 5. 4. 3. 2. 1.
rest
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5
June
July
: 0.3 birds per hour
: 3 birds per hour
: More than 30
: More than 50
: More than 70

distribution with that of *R. tridactyla*, in map), *Larus glaucescens*, and *Aethia psittaculus*. Among migrants, northern breeding species such as Nordmann's Tern, skuas, etc., were found mainly in this division in late June, and *Pterodroma inexpectata* represented a southern hemisphere migrant. Further subdivisions with different sea bird densities were as follows:

a. Bering Sea waters: Bird density was very low but *Rissa brevirostris* was relatively common. Birds of this species contained a large amount of body fat, but one collected specimen of two *Rissa tridactyla* encountered was entirely devoid of fat. Possibly both were stragglers.

b. Attu–Commander Is. waters: Towards the Commander Is., the fulmars increased, showing clustered distribution around discarded viscera of whales. Apparently food supply was abundant near the islands and bird density was high. A big mixed flock of *Fulmarus glacialis* and *Puffinus tenuirostris* (and of other sea birds and the porpoise, *Phocaenoides dallii*) was devouring euphausids at dawn, June 23, west of Attu, where meeting lines of currents occurred and some southerly summer winds were blowing. East of Agattu, where there was a strong local water current, alcids such as *Aethia psittaculus* and *A. pusilla* were abundant. *Rissa tridactyla* was not uncommon but no *R. brevirostris* was seen.

c. Transitory waters: A generally pelagic zone with medium bird density. Main species were: *Fulmarus glacialis, P. tenuirostris, O. furcata*, and *O. leucorhoa*, as well as occasional *Pterodroma inexpectata*.

d. S. Kamchatkan offshore waters: Bird density, especially of *Fulmarus* and *P. tenuirostris*, was again high and a marked concentration of *O. furcata* was found. *Lunda* and *Uria* (mostly *U. aalge*) as well as skuas (*Stercorarius pomarinus* and *S. longicaudus*) became common, while *R. brevirostris* (total seen 113) outnumbered *R. tridactyla* (total seen 36), June 25–July 5.

2. Offshore Kuriles division

A stretch of sea surface influenced by cold winds and waters of the Okhotsk Sea. The bird density was sparse, the dominant species being *Fulmarus* as usual. *O. leucorhoa* outnumbered *O. furcata*, which decreased towards the south. *Lunda* was found scattered and *R. tridactyla* occurred, but *R. brevirostris* was not observed. *Aethia cristatella* was found extremely localized off Shinshiru Is.

B. *Offshore Kuriles Convergence (180–200 miles offshore)*

Outside the Kuriles cold current a zone of convergence was found between the cold current and the periphery of the warm current, and some demarcating lines were noted. A change in relative abundance was noted, *O. leucorhoa* becoming the dominant species, and *O. furcata* and *Fulmarus* as well as *Lunda* decreased. *Diomedea immutabilis* seemed to be most suited to this intermediate temperature zone, while warmer adapted species, such as *D. nigripes*, and *Pterodroma solandri* (first recorded in this zone) began to appear.

C. *Offshore Warm Current Sea Surface*

At a point just north of 41° N., 240 miles E.S.E. of Kushiro, Hokkaido, the periphery of the warm current was reached; there the sky cleared up and the sea was very blue and calm with gentle southern breezes (air 22° C. and water 15° C.). Such fish as the swordfish, sharks, and sunfish, which characterize the warm current, occurred there, and *Phocaenoides dallii* was replaced by *Lagenorhynchus obliquidens*, while the sperm whale was observed in family groups. A radical change in bird species was noted. No species occurred in large flocks, which, perhaps, was evidence of the scarcity of plankton, the basic food supply. In this zone *D. immutabilis* was replaced by *D. nigripes* and *O. leucorhoa* by *O. castro*. Such southern hemis-

FIG. 2. Distributional patterns of sample species in the Northern Sea division.

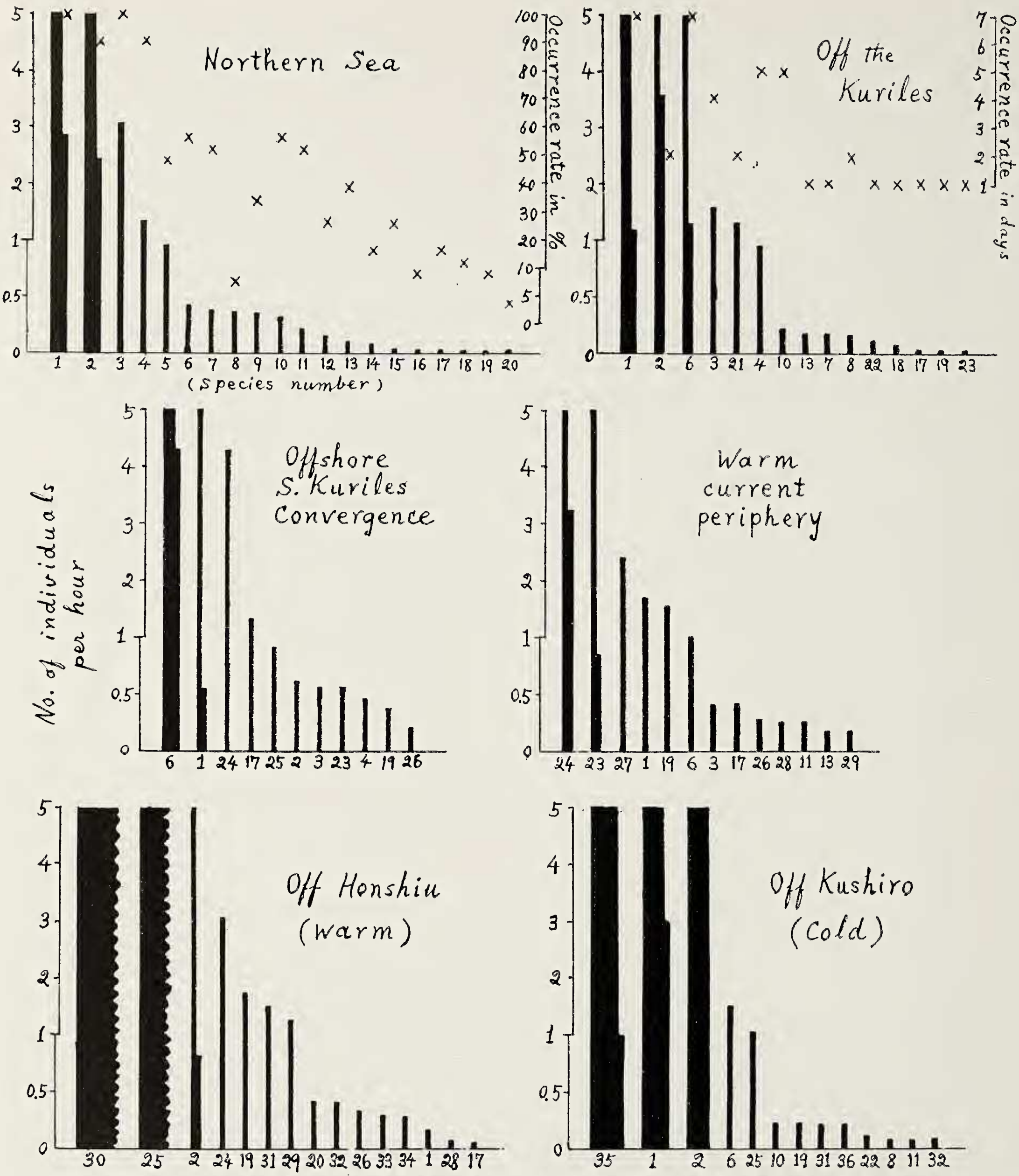


FIG. 3. Relative abundance (number of individuals per hour) of all of the species of sea birds recorded in each sea division. Species numbers indicate: 1. *Fulmarus glacialis,* 2. *Puffinus tenuirostris,* 3. *Oceanodroma furcata,* 4. *Lunda cirrhata,* 5. *Rissa brevirostris,* 6. *Oceanodroma leucorhoa,* 7. *Rissa tridactyla,* 8. *Aethia pusilla,* 9. *Aethia psittaculus,* 10. *Uria* sp., 11. *Stercorarius longicaudus,* 12. *Pterodroma inexpectata,* 13. *Stercorarius pomarinus,* 14. *Larus glaucescens,* 15. *Sterna hirundo longipennis,* 16. *Synthliboramphus antiquus,* 17. *Diomedea immutabilis,* 18. *Fratercula corniculata,* 19. *Diomedea nigripes,* 20. *Phalaropus fulicarius,* 21. *Aethia cristatella,* 22. *Brachyramphus marmoratus,* 23. *Pterodroma solandri,* 24. *Oceanodroma castro,* 25. *Puffinus griseus,* 26. *Synthliboramphus wumizusume,* 27. *Puffinus bulleri,* 28. *Catharacta skua,* 29. *Puffinus carneipes,* 30. *Calonectris leucomelas,* 31. *Larus crassirostris,* 32. *Lobipes lobatus,* 33. *Cerorhinca monocerata,* 34. *Oceanodroma tristrami,* 35. *Larus schistisagus,* 36. *Larus canus.*

TABLE 3

ANALYSIS OF POPULATION DENSITIES AND PATTERNS OF CHIEF SPECIES OF SEA BIRDS IN THE "NORTHERN SEA DIVISIONS," 12 JUNE–5 JULY 1954

SPECIES OF BIRDS	ECONOMIC DENSITY			NUMBER OF INDIVIDUALS PER HOUR		OCCURRENCE RATE‡	LOWEST DENSITY
	Variation	Mean	S.D. (6)	Mode†	Mean		
Fulmarus glacialis	0.3–12.2 *32.9–76.2(5)	12.86	19.0	1.4–3.2	2.43	1.00	12.86
Puffinus tenuirostris	0.3–17.8 *46.6–60.8(3)	13.69	18.0	1.2–3.7	2.19	0.91	12.45
Oceanodroma furcata	0.1– 4.6 *40.0	3.07	8.0	1.1–2.3	1.58	1.00	3.07
O. leucorhoa	0.1– 4.0	0.73	0.9	0.1–0.4	0.28	0.56	0.41
Lunda cirrhata	0.1– 3.7	1.46	1.0	1.1–3.7	2.18	0.91	1.33
Uria spp.	0.1– 2.1	0.55	0.6	0.1–0.2	0.20	0.56	0.31
Aethia psittaculus	0.1– 4.8	1.00	1.5	0.1–0.6	0.43	0.34	0.34
Rissa brevirostris	0.1– 6.5	1.92	1.9	0.2–2.7	1.90	0.47	0.90
R. tridactyla	0.1– 2.0	0.73	0.6	0.1–0.2	0.13	0.52	0.38
Stercorarius longicaudus	0.1– 1.8	0.39	0.4	0.1–0.3	0.16	0.52	0.20

* Indicates concentrated or "highest" density: 5 cases in *Fulmarus*, 3 in *P. tenuirostris*, and 1 in *O. furcata*. These are included in the means.

† The mode indicates most frequent densities, exclusive of unusual or "highest" densities.

‡ Occurrence rate is the ratio between the number of days the species occurred and the total of 23 observation days. The lowest density is the mean economic density × the occurrence rate.

phere migrants as *Pterodroma solandri* and *Puffinus bulleri* (first recorded) were common, and a few *Puffinus carneipes* and *Catharacta skua* occurred, while *Synthliboramphus wumizusume* reached there from its Japanese breeding waters.

D. *Japanese Waters*

1. Warm waters off Honshu

The oceanic conditions are similar to area C above, but the water temperature was lower (12°–13° C.), and cold and warm currents were distinguished at about the latitude of Cape Erimo, Hokkaido. *D. nigripes* became common south of that latitude and *P. carneipes, O. castro,* and *Catharacta skua* occurred, while a few *Fulmarus* and a single straggler of *O. furcata* were seen south to 143° 42′ E., 41° 23′ N. Two *Fulmarus* were sighted as far south as Iwate, Honshu. The coastal waters of Sanriku (N. Honshu), where currents meet and which are rich in food supply, were the main summering grounds of *Puffinus griseus.* Nearer to the coast, some 2,000 *Calonectris leucomelas* were observed off Yamada Bay, apparently over a shoal of sardine; *P. griseus,* with a weaker bill, prefers to feed upon euphausids. These two species were responsible for the very high population density of this coastal zone.

2. Cold waters off Kushiro, Hokkaido

In this southern limit subdivision of the cold northern waters, *Fulmarus* and *P. tenuirostris* were again numerous and *Larus schistisagus* and *Brachyramphus marmoratus* occurred in coastal waters.

CORRELATION WITH FOOD SUPPLY

The abundance of plankton, a basic food supply of sea birds, is correlated with local upwellings of the sea which are caused by sea bottom conditions (especially near islands), and currents as well as winds. A special study of

DATE	SEA AREA	PLANKTON	POLLACK ANGLED	NO. OF BIRDS OBSERVED
June 17	Near Agattu	Very scarce (collected)	15	61
June 18	Agattu-Kiska Strait	—	49	285
June 22	60 m. E. of Commander Is.	Abundant (collected)	Scores	190
June 23	W. of Attu Is.	Abundant (euphausids)	—	659 (A big flock)
June 26	200 m. S. of Commander Is.	Scarce (collected)	—	77

plankton was not made, although in some collections made for the Fisheries Bureau, *Sagitta* species were very abundant locally, but the following may show some relationship with bird density.

Pollack were caught for a short time after sunset by 4–5 crew members, and it is indicated in the data above that a correlation exists among abundance of plankton, pollack, and sea birds. In the tropical Pacific, Thompson (1951) found a parallel increase of jellyfish and the black-footed albatross toward cooler waters, and from his observation he derived a "Jellyfish Index." In the above case, the "Pollack Index," the number angled per unit of time by the same persons, might serve as an index of productivity in northern seas.

TEMPERATURE PREFERENCE IN SOME SEA BIRDS

As mentioned above, the sea birds are either cold or warm adapted, therefore temperature dependent in distribution. This is best shown by the Tubinares, as briefly described below (see Fig. 4).

THE ALBATROSSES: Of the two species, *Diomedea immutabilis* is less warm adapted. It was commonest in the convergent sea surface, and *D. nigripes* distinctly preferred the warm current zone. But even the latter species is not a tropical bird. Thompson (1951) reports an increase in number as the water temperature decreased from 27.7° C. to 14.4° C. in the eastern Pacific. During its winter breeding season, the air and water temperatures around the subtropical islands, Torishima or Bonin Is., are both below 20° C. The temperatures markedly increase during the summer when *D. nigripes* moves north to cooler waters. This cool adaptation could explain their winter reproductive cycle, which is unusual for the northern hemisphere (Kuroda, MS). From my observation, the temperature preference of the two species is suggested below.

	D. immutabilis	*D. nigripes*
Air Temperature (°C.)		
Range	6.2–22.5	7.0–22.5
Preferred	13–15	17–22.5
Water Temperature (°C.)		
Range	5–15.5	5–16
Preferred	7–8	10–16

THE STORM PETRELS: Both *Oceanodroma furcata* and *O. leucorhoa* are cold adapted species, although the latter shows wider temperature adaptation as it migrates in winter to tropical waters. Zoogeographically their main distribution ranges were segregated north and south, although they overlapped. A distinct concentration of *O. furcata* was found in the north in waters east of south Kamchatka (air temperature, 7–8° C.; water temperature, 5.6–7.3° C.), while concentrations of *O. leucorhoa* occurred in the Offshore Kuriles Convergence (air 13–15° C., water 6.6–8° C.), where *furcata* decreased. But just north of this concentration, *O. leucorhoa* also showed a clustered distribution, both on June 11 and July 6, within the cold Kuriles current (air 3.5–4 and 9.2–11° C., water 2.3–3 and 5° C.). In this case, too, the

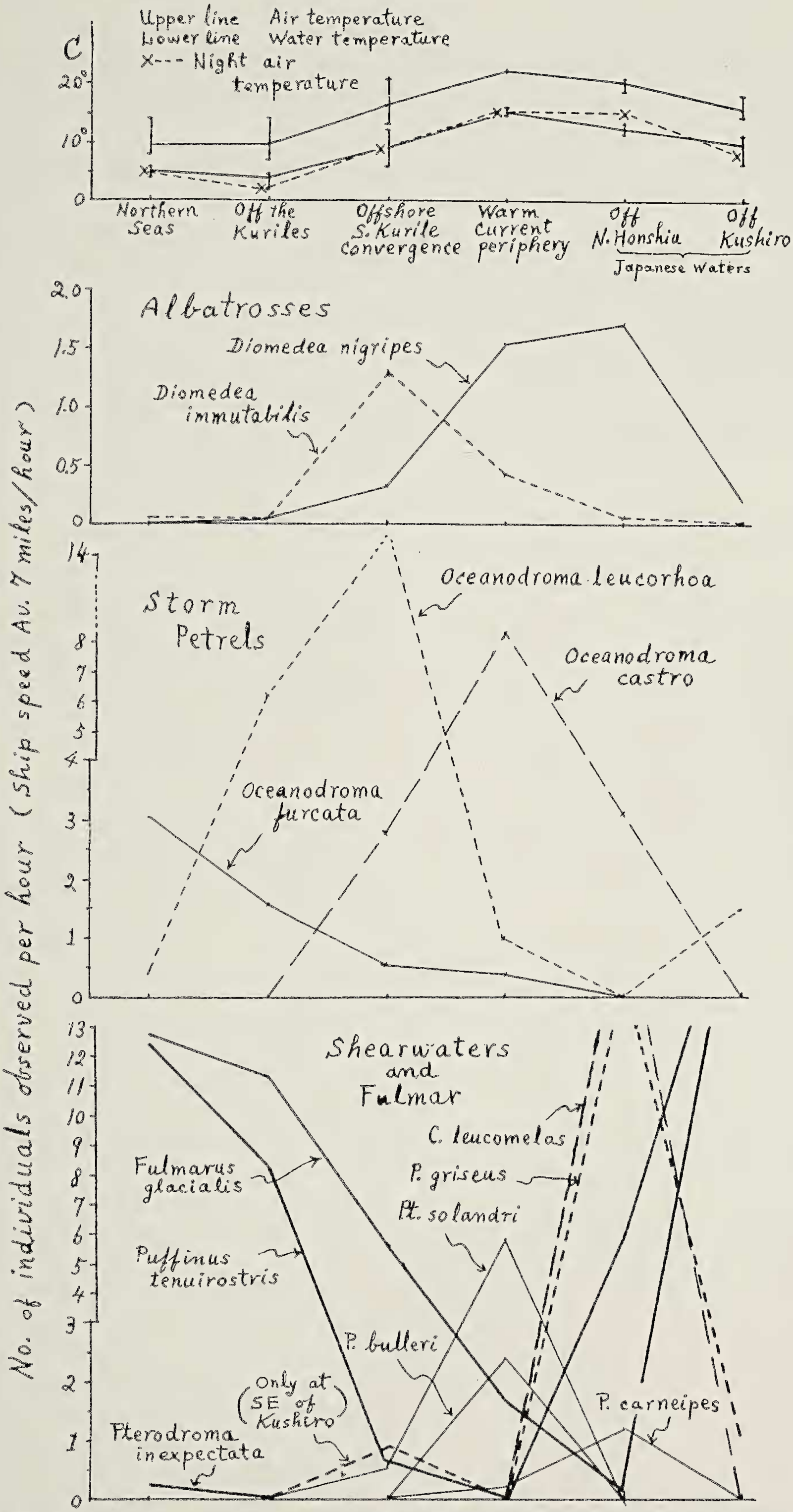


FIG. 4. Specific relative abundance of the Tubinares in different temperature zones.

TABLE 4
POPULATION DENSITIES OF SEA BIRDS IN THE SEA DIVISIONS INVESTIGATED

	COLD CURRENT		OFF-SHORE SOUTH KURILES CONVERGENCE	WARM CURRENT PERIPHERY	JAPANESE WATERS		TOTAL OR AVERAGE
	Northern Sea	Off the Kuriles			Off Honshu (warm)	Off Kushiro (cold)	
Number of days of navigation	23	7	2	1	2.5	2.5	37
Total number of birds observed	4136	761	309	160	2699	983	9048
Number of birds observed per day (average)	31–604 179.8	39–281 108.7	154.5	160.0	1075.6	392.2	345.1
Number of birds observed per hour (average)	3–118 32.12	5–46 17.55	28.82	21.42	323.66	71.66	82.54
Number of species observed	20 Av. 10.5	15 Av. 5.8	11 Av. 7.5	13 —	15 Av. 7.5	13 Av. 6.6	37 Av. 8.5

decrease of *O. furcata* was recorded, but whether *leucorhoa* dominates *furcata* is not certain. It is to be added that on June 11, all of the birds (*O. leucorhoa*) were steadily moving eastward, which suggested a migration out of the most suitable temperature zone in accordance with some oceanic conditions. Thus, the range of temperatures recorded for *leucorhoa* was much greater than for *furcata,* while *O. castro* was distinctly a warm current species.

	O. furcata	*O. leucorhoa*	*O. castro*
Air temperature, °C.	5–11.5 Rarely 12–14 A straggler at 21	3.5–22 Mostly 7–15 Especially 13–15	16.5–22.5
Water temperature, °C.	3–8 Once 11 A straggler at 15.5	2.3–16 Especially 6–8	10.8–16 Rare at 8

THE SHEARWATERS AND FULMARS: *Puffinus tenuirostris* and *P. griseus* showed distinct segregation to cold and warm currents respectively. The former was one of the commonest species in the northern seas, though it was rare off the Kuriles, but it was again found mixed with numerous *griseus* in warmer Japanese waters. The latter species was never found in the cold waters except for a few off Kushiro east of the convergence, but it was not 'seen on the offshore true warm current surface. Other migrant southern hemisphere species, and the fulmars and the Japanese streaked shearwater (*Calonectris leucomelas*), preferred the following temperatures.

	AIR TEMPERATURE °C.	WATER TEMPERATURE °C.
Puffinus tenuirostris	6–11.5 A few 17–20	3.5–7 A few 14.8–15
P. griseus	17–20 A few 7	11.2–12.5 A few 8.2
P. carneipes	16.5–20.7	10.8–16
P. bulleri	18.5–22.5	14.5–16
Calonectris leucomelas	19–20	12–12.5
Pterodroma solandri	12–22.5 Once 7	7.5–16 Once 6.2
Pt. inexpectata	6.2–9	5–6.2
Fulmarus glacialis	6–11.5 A few 17–20	3.5–7 A few 14.8–15

Synthliboramphus wumizusume was distinctly restricted to the warm currents, unlike all of its relatives, which are cold current birds. *Catharacta skua,* from the cool waters of the southern hemisphere, also was restricted to the warm current surface in this sea zone, while the arctic breeding skuas were found in cold currents, except for three individuals which were migrating across the warm current waters.

SUMMARY

1. During a research cruise from Japan to the west Bering Sea, June to July, 1954, a sea bird census was made.

2. As an indication of population density, the number of birds observed per hour was used. The speed of the ship averaged 7 miles per hour, and the number of birds per square mile was calculated for sample sea divisions.

3. Attempts were made to show a correlation of bird density with food supply.

4. Distribution of sea birds is subject to zoogeographic factors (endemism) and to ecological factors (food and temperature), as well as to seasonal physiological cycles and movements. Sea zones were divided according to air and water temperatures and to relative abundance of sea birds.

5. The distribution pattern was different for different species of sea bird. Flocking species, although generally distributed, showed a clustered pattern, concentrating where food was abundant, while solitary species were distributed at random, since sparse amounts of food suffice for them.

REFERENCES

AUSTIN, O. L., JR., and F. WILKE. 1950. Japanese Fur Sealing. Nat. Resources Sect., GHQ, Rep. 129. Tokyo.

CANADA, JAPAN, and U. S. GOVERNMENTS. 1954. Distribution and Food of North Pacific Fur Seal. Rep. Int. Res. (Japanese translation, Fisheries Bureau, Tokyo).

ELTON, C. 1932. Territory among wood ants (*Formica rufa* L.) at Picket Hill. J. Anim. Ecol. 1: 69–76. (Also presented in Elton, C. 1953. The Ecology of Animals. 97 pp. Methuen, London. The reference quoted is to p. 51 of this book.)

KURODA, N. 1955. Observation on pelagic birds of the northwest Pacific. Condor 57(5): 290–300.

——— 1956. Records of pelagic mammals observed in the northwest Pacific. J. Mammal. Soc. Jap. 1(3): 36–39.

ODUM, E. P. 1954. Fundamentals of Ecology. Philadelphia & London.

THOMPSON, D. Q. 1951. Notes on distribution of North Pacific albatrosses. Auk 68(2): 227–235.

TORII, S. 1952. Methods of measurement of insect population. IN Outline of Ecology, edited by S. Yagi and K. Nomura. Yokendo, Tokyo. (In Japanese.)